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ANALYSIS OF MODUGANARI SILICA-CLAY SAND FOR FOUNDRY APPLICATION

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ABSTRACT

The paper presents the suitability of silica clay sand that are very available in Maiduguri Metropolis, with emphases of Moduganari Silica Clay. The work ascertained its physical and chemical properties for use in foundry. All the test samples collected from various areas were subjected to relevant sand mould test, such as bonding strength, permeability test, refractoriness test, moisture content test and sieve analysis. The grain size shows a highly concentrated distribution of 80.9%. The most important property of silica clay sand includes the shape of the sand particle and size distribution. Sieving process was used to obtain the uniform grain size of the soil sample. Moisture content has great effect on the silica clay sand at varying quantity of moisture found in the sand. Higher value of bonding strength shows that mould produced would have more resistance to wear. Moduganari sand has shown increased permeability number which provides better venting ability that can help in eliminating defects like blow and holes in the mould when a molten metal is poured. The silica sand is used predominantly due to its chemical resistivity, which makes it not to chemically react or combine with molten metal during casting processes, a clear indication of repeatable application.

KEYWORDS: Foundry, Clay-sand, Bonding Strength, Grain size, Defects, Properties

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INTRODUCTION

While metal casting is also called founding, foundry is a commercial establishment for founding or producing castings (Ibhadode 2001). There are various types of foundry method: die or precision casting, shell moulding, investment casting, centrifugal casting and sand casting. Sand casting is the most commonly used method.

Though there are many known deposits of silica sand, clay and the availability of additives in the country, the determination of foundry properties of these materials has not being methodically carried out in so many foundries and also the composition of the sand that gives the optimum water content has been rarely evaluated. These have become important process to establish the best properties that can be derived from a particular sand deposit that is readily available for foundry use in the country. In moulding of iron, steel, non-ferrous or light alloy casting, the principal moulding material is sand, so it is very important to know the composition in order to be able to control the day-to-day foundry operations. Furthermore, Aiyedun *et al.* (2012) have reported the use of Osiele clay as refractory material without the use of additives. This is a positive result, which can reduce the cost of foundry practices in most part of Nigeria. The very early Man, whether prehistoric or present, fashion clay by digging out a hole and allowing it to dry in the sun or in open fire (Callister, 1996). There are vast deposits of clays in Borno and Yobe (Orumwense and Nwajagu 1992) and their viability has been investigated to some extend by Aji *et al.* (2009). Results showed that some of the clay contains low alumina and low refractoriness due to their high silica content that makes it expand easily on heating. Ibhadode (2001), described most commonly used refractory materials include fireclay, high alumina, Magnesia and Dolomite. Nnuka et al. 1992 pointed out that refractory clays are those which primarily consist of 46-62% Si and 25-39% Al_2O_3 in their composition.

Moulding sand can be defined as a raw material used in making of mould which contain a binding materials usually in the form of clay and occasionally with a small proportion of organic compound, which are all moistened suitably with water to impart plasticity (Bcira, 1985). The need for systematic evaluation of working properties and qualities of moulding materials under foundry condition has led to the development of a wide range of test. Green sand moulding is the main moulding process used in more than 80% of UK's foundries despite all the competition from chemical binders such as resin and silicates (Bcira, 1985). Some of the tests are concerned with the basic chemical and physical characteristics, but majority are designed to measure the bulk properties. The bulk properties of an aggregate are sensitive to small variation in mixing condition and specimen preparation such that rigid standardization is needed at all stages. There producibility of the test has been shown in permeability and least in dry strength determination. (Morey and Ackelind, 1941) The required property of the sand will vary according to the type of work being carried out, for example, for light or heavy casting, plain carbon or high carbon alloyed steel are used in mechanized or jobbing foundry.

There are many known deposit of silica sand all over the country, which can be used as moulding materials for casting, but are lying idle or un-assessed, and therefore the need to analyse the silica at Moduganari, so that the deposit will adequately and effectively be utilized for foundry application. Market and technology trends show that metal casting industry believes in development that will have lasting effects in years to come. Since most casting production still takes place in sand mould, a great deal of attention need to be paid to the preparation, control, handling and correct application of moulding sand (Brown, 1994). Clay (binder) is added to give cohesion to the moulding sand and also provide strength that enables it to retain its shape as mould cavity. This work analysed the properties of Moduganary silica-clay sand for foundry application.

MATERIALS AND METHOD

The materials used for this research is silica clay sand which is the chief raw material of any foundry industry. Some of the silica clay sand are cohesive when mixed with a limited amount of water. All the materials required for this research were sourced locally. The silica sand was sourced from Maiduguri at Moduganari ward near Kano Motor Park. Each of the tests specimen/samples from samples obtained were subjected to relevant sand mould test such as bonding strength, permeability test, refractoriness test, moisture content test and sieve analysis. The entire tests were carried out with the sand testing equipment at various departments of University of Maiduguri. The samples were prepared in accordance with the standard specification for moulding test. i.e. Test sample specimens were prepared for laboratory experiment from various moulding sand sample.

Sample Preparation

The required quantity of the silica clay sand and water for each of the samples were measured in accordance with the varying proportion and put into the laboratory mixer and then mixed for about five minutes. When thoroughly mixed, the mixture was discharge through the discharge opening at the bottom of the mixer. The quantity that gave the required size of 5cm diameter x 5cm height was weighed on the weighing balance and then poured into the specimen tube. The weight differs for different mixtures of sand component. The tube with the sand sample inside it was positioned in the specimen rammer and then rammed with the three drop of standard weight. After ramming, the specimen was injected from the tube with the aid of specimen extractor. This procedure was repeated for the preparation of the standard test specimens for the various compositions of the moulding mixtures.

Materials/Equipment Used

Weighing balance: used in the weighing of soil sample to obtain the weight of the sample for sieving

Sieves: sieves of different sizes and mostly made of woven wire clothed in the order of 2.00mm, 0.6mm, 0.39mm, 0.15mm, and 0.075mm. They are used for sieving the soil sample which helps avoid defects in casting.

Sieve shaker: It is the device that the sieves are being tightened in to sieve for a giving period of time in order to obtain a uniform grain size of the soil sample.

Stop watch: It is used in determining the time for analysis of each sample during the test.

Electric oven: used for heating the soil sample, it has a temperature control
Manometer: Used in the determination of air that flows through the soil sample

Specimen tube: used in the measurement of quantity of soil sample for permeability test

Electric furnace: a device with very high temperature which is also used a heating device with temperature ranging from1000^0 C to 1500^{0}C.

Grain Size Analysis
The stock of sieve were arranged according to the sieve aperture starting with the largest aperture on top of the stock and then smallest at the bottom (on top of a pan). The samples were dried in the air and some quantity of the sample was taken on to the top of sieve stock and the stocks was placed on a sieve shaker and then switched on.It was set to allow for vibration for a period of fifteen (15) minutes. The sieves were removed one after the other beginning with one on top. The quantity of sand remaining on each sieve was weighed, and was recorded accordingly with each sieve in a column corresponding to the sieve mesh number, i.e., British Standard Sieve number (BSS). Each separate sieve weight was multiplied by the preceding sieve mesh number. The sum total of the product was divided by the total sample aligned and this produce the fineness number of the sand. This analysis help in obtaining the uniform grain size of the soil sample in order to avoid defect in casting. The amount of clay among silica sand is very important in that they keep the mould together with great strength.

Moisture Content Analysis
Moisture content is another important property of moulding sand. The level of moisture acceptable in sand is usually 4-7%. Moisture causes the sand to swell thus affecting the accuracy of casting. Metal mould reacts with higher moisture content in the sand mould. The hot air method was employed to determine the moisture content in order to dry the wet soil sample. The apparatus was switched on and allowed to heat up for some times. 100g, 150g and 200g of the prepared sand was measured and placed in the pan provided at the base of the instrument. The thermostat on the equipment was set to 1100^{0}C and the drier was set in operation by means of a timer switch. The dried sample of the sand was then allowed to cool and it was reweighed. So the moisture content of the sand was then determined. The moisture content of the sand is the most important variable, as on this all other properties depend. Moisture content is defined as the amount of water present in the moulding sand, low moisture content does not develop strength properly while high moisture content decreases permeability.

Test for Refractoriness
High temperature test are relevant foundry conditions since they enable mould material to be assessed under certain conditions. Refractoriness is the ability to withstand high temperature i.e. the ability for the mould to withstand high temperature. This was carried out with the help of an electric furnace a temperature range of 1000^{o}C to 1500^{o}C. The appearance of the sample was observed with increased in temperature. A good expansion after cooling indicates good sand where poor sand show shrinkage.

Bonding Strength Test
Bonding strength indicate how the mould is likely to behave when subjected to the stresses either as a result of molten metal cast into it or due to the heating and cooling of the mould. This property is also an indication with which pattern can be withdrawn from the mould. This was carried out with the help of a shear box. The vertical displacement of the shear box dial indicator is an indication of this property.

Permeability Test

This is the rate of air passage through a given sample. It is the rate of pressure that can flow through a soil sample. This test was carried out using a manometer. The permeability test was carried out on the standard sample specimen of 5cm diameter x 5cm height. The specimen, while still in the tube, was mounted on permeability meter. The permeability meter employs orifice method for rapid determination of sand permeability. Air at constant pressure is applied to the standard sample specimen, immediately after producing the sample and the drop in pressure is measured on the pressure gauge, which is calibrated directly in permeability numbers.

RESULTS AND DISCUSSION

Sieve Analysis of Moduganari Silica Clay Sand

The results obtained during sand test were recorded and presented in a tabular form (1 – 7). The tables below represents the results of sieve analysis, while the remaining tables reveals the effects of varying additives with constant volume of water on the bonding strength, refractoriness test, permeability test and moisture contents respectively.

Table 1: Sieve analysis of Moduganari silica clay sand for 100g

Mesh sizes (mm or µm)	Quantity of sand (g)
2mm	5.51
1mm	10.41
850µm	2.83
710µm	3.15
500 µm	6.60
425µm	3.90
300µm	9.16
250µm	2.61
150µm	17.99
63 µm	28.74
Pan	8.18

The results of sieve analysis and moisture content of the soil are presented in Tables 1 and 2, showing the size distribution of the soil and moisture retained in soil as at the time of research. The tables showed that the soil used is classified as clay (Fig 1).

Table 2 showed the moisture content analysis of Moduganari silica clay sand for 100g. Moisture content has effect on the silica clay property. The analysis shows that low moisture content does not develop good strength also high moisture decrease permeability of the soil.

Table 2: moisture content analysis of Moduganari silica clay sand for 100g

S/No		
1	Can number	51.4
2	Weight of empty can (g)	27.90
3	Weight of can + wet soil (g)	83.80
4	Weight of can + dry soil (g)	183.00
5	Weight of water (g)	3.2
6	Weight of dry soil (g)	150.00
7	Water content =weight of water x 100=3.2/177.90x100	2.60g

$$\text{Moisture Content} = \frac{W_w}{W_c + W_d} \times 100$$ where,

W_w = weight of water
W_c = weight of can
W_d = weight of dry soil

Average percentage moisture content $M = \frac{M_1 + M_2 + M_3}{3} = 2.55$

The refractoriness test shows how high temperature test are relevant in foundry condition since they enable the mould material to be assessed under certain conditions. The results showed that at 1000 to 1200^0C there was no reaction or changes in soil structure. However, 1300 to 1350^0C showed the bonding effect of temperature on soil, and as the temperature increased to 1400^0C the soil failed (sintered). This indicated that high temperature has negative effect on the silica clay.

Table 4: refractoriness test result of Moduganari silica clay sand for 100g

Temperature °C	A (100g)
1000	A
1050	A
1100	A
1200	A
1250	A
1300	B
1350	B
1400	C

Key
A = No reaction
B = Sticking together
C = Sintering (process in which the particle of powder are welded together by pressure and heating, when heated to a temperature below its melting point)

The permeability test of silica clay sand was relatively high, indicating that the soil is capable of allowing movement of water and heat from it (Table 5).This indicated better venting ability of the soil.

Table 5: Permeability test result of Moduganari silica clay sand for 100g

Ring number	**R – 17**
Weight of ring	98.00
Weight of soil	100g
Weight of ring + soil (g)	198.00
Length of ring (mm)	47.70
Initial flow (cm)	4.00
Final flow (cm)	6.80
Head causing flow	2.80
Time t (min)	1.50
Quantity of flow Q (cm)	30.00
Area of ring $A = \pi D^2/4$	17.87
$K = \frac{Q}{Z \times A}$ (cm/min)	2.24

Average K = 3.39 cm/min; R – 17 = Ring number

The result (Table 6) showed increased in bonding with time increased. This indicated that too much strength applied on the soil would cause damage to the soil. Because bonding strength indicate how the mould is likely to behave when subjected to stress either as a result of direct quantity of molten metal cast into the mould or due to the heating and cooling cycle of the mould.

Table 6: Bonding strength test result of Moduganari silica clay sand for 100g

Weight of core cutter (g)	1st Reading (167.2)
Weight of soil (g)	100
Weight of core cutter + soil (g)	267.2
Test load (kg)	6
Time (min)	Dial / Reading
0	00
1	38
2	54
3	62

CONCLUSIONS

The following conclusions were drawn from the test conducted:

i. The mixture of silica sand and some percentage of water was the best mixture and its properties compares favourably well with the properties of the moulding sand currently in use in foundries for production of small and medium size iron casting.
ii. Sieve analysis also reveals that the grain size of the sand was sub-granular and their AFS number shows that it was relatively fine sand.
iii. Moisture content has effect on the silica sand property at varying quantity of moisture of the silica clay sand
iv. The higher value of the bonding strength shows that the mould produced will have more resistance to wear and external pressure.
v. Increase in permeability number shows that Moduganari silica clay sand has better venting ability
vi. The sand showed good refractoriness which is acceptable for use in foundry application.
vii. The silica sand at Moduganari ward will be most suitable casting or any non-ferrous metals. It can also be employed for small to medium iron casting.

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